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REVIEW ARTICLE

Laser Therapy and Osteoarthritis Disability: An Updated Snapshot Highlighting Highly Promising Cartilage Regeneration Associations

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Abstract

Among the various non-pharmacological interventions shown to partially relieve painful disabling osteoarthritis, the most prevalent joint disease, laser therapy, initially reported as highly efficacious in Russia and Eastern Europe remains less well accepted in Western medicine contexts and especially as a salient and effective mobility restorative modality. Building on prior research, the present 2020-2024 data review aimed to:

a) update the degree of support for continuing to research this topic, in general,
b) its cartilage regenerative/repair potential, commonly believed unachievable and tenable, in particular.
While not studied clinically to any degree, most experimental studies support a specific role for possible cartilage repair plus possible post-treatment improvements in symptoms associated with osteoarthritis, including pain, mobility, and function. Possible documented mechanisms for the observed results include the resolution or attenuation of pain and inflammation, enhanced cartilage tissue cell proliferation and increased matrix synthesis.

Keywords: articular cartilage, efficacy, high intensity laser, inflammation, intervention, low-level laser therapy, osteoarthritis, phototherapy, regeneration, repair, tissue engineering

Background

Osteoarthritis, the most prevalent form of arthritis is a widespread disabling disease that continues to induce immense physical and socioeconomic challenges, plus enormous health care costs among many aging citizens in all countries as well as affecting younger adults. Predominantly impacting the cartilage tissue that lines freely moving joints such as the knee, the disease tends to progress in magnitude and severity because this key tissue designed to absorb daily joint impacts has been shown to have a limited reparative capacity in the older adult or in the face of severe joint injury. In addition, pain, the key feature of osteoarthritis often reduces mobility and motivation plus physical energy for moving the joint that can result in its further attrition.

While generally impervious to regeneration even in the face of novel pharmacologic interventions, some evidence has accrued over the years implying electromagnetic light waves and others may potentially offer a means of positively reversing or ameliorating some of the pathology of osteoarthritis, including cartilage repair.[1-4] In particular, although not mentioned in the present 2023 EULAR recommendations for osteoarthritis conservative management,[5] laser light applications of various modes appears to be a well established form of biophysical energy that may have the ability to not only alleviate pain through its potential impact on joint inflammation and accompanying adverse bone, ligament, and muscle alterations but can likely foster some form of cartilage protection/repair.[6] Indeed, while not a cure for osteoarthritis per se, laser therapy, used alone or in conjunction with other approaches may yet prove highly beneficial not only for fostering mobility and a life of high quality, especially important in older adults, but in helping to limit its progression.[7-10]

Moreover, even if discounted in favor of exercise[11] given that not all older adults can exercise readily and must otherwise rely on medications listed for alleviating osteoarthritic pain and inflammation and/or injections that may prove injurious, a modality that can be applied readily with possible implications for mitigating the disease progression and its possible regression, may have an enormous impact, including multiple social and economic ramifications, even if surgery is eventually required.[12-14] In addition, its application when combined with other intervention modes appears promising.[13-17]

However, despite its strong theoretical and pre-clinical record of safety and efficacy and demonstrated pain relieving impacts, its potential as a disease modifier is rarely reported or remains somewhat in question.[11,18]

Building on what is known in this realm, we currently chose to specifically update what has been shown over the past five years when laser therapy in any form is applied to osteoarthritis type cartilage damage directly or as a cartilage repair or regenerative analog and whether this form of electromagnetic energy offers a sufficiently valuable and promising line of future inquiry in efforts to avert osteoarthritis debility as suggested by Lu,[16] Oliveira,[19] and Hwang.[20]

Rationale

Osteoarthritis and its key tissue site of influence, namely cartilage is generally accepted as being unable to undergo repair, regeneration, or adequate healing. However, laser light pulses when marshaled or harnessed and applied to osteoarthritis cartilage in diverse animal models believed to represent the disease, have not only been observed to have the potential to reduce osteoarthritis associated pain and inflammation that may ward off excess cartilage destruction,[25,26] but to foster some degree of repair in variously injured joint support tissues affected by osteoarthritis, such as cartilage.[27] Unlike clinical studies, laser light applications and their resulting impacts appear worth studying in the lab as a first step because these are more reproducible and findings are less likely to be spurious or confounded by subjectivity, and appear to consistently induce measurable improvements in intercellular cartilage matrix synthesis without evidence of increased matrix catabolism that could prove of high value to transfer clinically.[19,27]

Methods

To update our understandings of how laser light is being studied as far as cartilage attrition is concerned we elected to consult the **PUBMED, PubMed Central, Science Direct,** and **Google Scholar** data bases with a focus restricted largely to the past five years, and to pre clinical studies, rather than clinical studies published between 2020-2024. The key search terms used were- ***articular cartilage and lasers, cartilage repair and lasers, lasers and osteoarthritis, laser pulses and chondrocytes, laser therapy and osteoarthritis, osteoarthritis and phototherapy***. Many publications were available showing a great interest in this realm, even if only 2024 is considered, numerous groups are examining laser light delivery and its impact on artificially induced cartilage damage including its ability to enhance stem cell and cartilage scaffold developments. To grasp the content and scope of these data, posted articles were first scanned and examined individually to uncover if the research report met the present inclusion criteria-of being a full length publication that has recently discussed some applications of laser intervention in experimental models of osteoarthritis and/or isolated cartilage tissues. All forms of laser application and research modes were deemed acceptable. Clinical studies examined elsewhere were not reviewed except for 2024 systematic review conclusions.[19] Prior data are similarly presented

only in so far as unifying current optical findings in the field that began in 1998.[10,19,22,23,28]

The article presented here does not however, examine cell based experiments of healthy cartilage cells or chondrocytes, lasers as a diagnostic tool, those related to rheumatoid arthritis, or laser irradiation effects on bone or other joint tissues. The validity of the osteoarthritis model used in the various studies was accepted as being reasonably representative of clinical osteoarthritis and able to thus offer insights into laser irradiation effects on destructive cartilage processes. The laser stimulation parameters employed and outcomes assessed and reported had to be those that could foster some degree of structural favorable change in the cartilage tissue such as cyclic hydrostatic pressure and inflammation control that might yet be applied to the human condition.

Cartilage was studied because superficial cartilage defects are an important factor that causes osteoarthritis and can have a key influence on its mechanical properties[29] and regenerative potential.[27]

Laser impacts were examined to determine if they have potential to repair or help restore damaged cartilage and cartilage defects to a more mechanically functional joint tissue status, rather than just ameliorating osteoarthritis symptoms such as pain and dysfunction that may or may not restore joint integrity or provide long-term relief and cost savings. The terminology was that used in the research and the terms laser therapy, phototherapy, and photobiomodulation were deemed to be comparable modes of light intervention or irradiation. Mostly anabolic impacts of laser were reported, although laser has the ability to be used to ablate rather than regenerate tissue.

Key Findings

In terms of a role for laser therapy in osteoarthritis cartilage repair, consistent with prior similar reports, the data bases selected for this updated review yielded- some strong support for laser therapy on osteoarthritis type cartilage states, as well as highly novel innovative research approaches related to osteoarthritis cartilage repair and lasers, regardless of osteoarthritis induced model or mode of introducing representative joint attrition processes or stimulation mode.

These data could largely be categorized as representing outcomes of single mode low or less often high intensity helium neon, infrared, pulsed Nd YAG, carbon dioxide, Holmium:YAG and Gallium-Arsenide lasers of varying modes as well as light emitting diodes and most show one or more of these modes of application to consistently reduce joint pain and inflammation in animal models as well as humans with osteoarthritis joint damage.[29] In addition, its application may reduce the extent of osteoarthritis related articular cartilage attrition and degeneration that would otherwise tend to generally progress over time.[30] According to Balbinot[31] who studied its impacts in a rat model of osteoarthritis, photo- or laser therapy may be effective in allaying osteoarthritis disease progression, fostering cartilage recovery and improving the inflammatory condition significantly and measurably. Earlier, Assis[32] who found that low-level laser therapy impacted knee osteoarthritis degenerative processes in the rat favorably concluded these findings were comparable to those attained by exercise or an exercise/laser combination.

Indeed, even if only 'positive' studies are being published, it is hard to refute the host of additional current studies that builds on those in the past and tends to clearly point towards laser light as having favorable impacts on the organization of articular cartilage of experimental models of arthritis while preserving the cartilage glycosaminoglycans contents.[33] In addition, when used in combination with samples of dynamic self-regenerating cartilage this combination of laser fractional laser ablation and implanted chondrocytes cells enhanced the ensuing cartilage repair processes.[34]

More recently, Wang[29] has shown that laser light applications can reduce superficially located defects within experimentally induced cartilage derangements and can duly change its surface morphology and structure, as well as its mechanical properties as a result.[35] When combined with stem cells, laser therapy similarly improves osteoarthritis states as observed in animal models of the disease and its analogues.[36-38]

Zue[39] similarly conclude that treatment with 1064nm Nd:YAG laser irradiation has the capacity towards promoting the proliferation and collagen secretion of chondrocytes and to thereby improve cartilage reshaping and stability. Lemos[40] also support this conclusion and imply laser treatments are effective in protecting and cleansing joint structures, while accelerating tissue repair, especially at lower doses.

Tim[41] who evaluated the effects of photo therapy in mediating chondrocyte responses in in vitro experiments showed that the laser pulse applications increased cell proliferation, and related anabolic factors that act on extracellular matrix. It was argued that the therapy led to a return to tissue homeostasis and fostered chondroprotective effects that stimulated the proliferation of key articular tissue components. Tanidah[35] support the view that combining intra-articular mesenchymal stem cells and laser therapy may effectively improve osteoarthritis outcomes, while low-level laser irradiation of cartilage results in its reshaping and tends

to stimulate regenerative or healing type reactions including the formation of new cartilage.[42] Yang[43] report that laser-treated chondrocytes located in a culture simultaneously maintained their differentiated phenotype and appeared to have the potential to repair cartilage lesions *in vivo* as well as restoring articular function via tissue engineering strategies.

In addition Wong[44] provide evidence that laser irradiation, along with other thermal and mechanical treatments can induce desirable chondrocyte proliferative responses, while Huang[45] argued in favor of its protective effect in the context of the degenerative intevertebral disc. In a rat model of osteoarthritis Martins[46] likewise found the application of laser therapy was effective in helping the arthritis induced joint tissues to recover from oxidative stress, while structurally preserving the articular cartilage tissue, a finding supported by Fekrazad.[33] In addition to preventing cartilage degeneration,[46] potentially fostering improved outcomes of cartilage stimulation in the context of 3-D cartilage scaffold printings,[47] and fostering cartilage repair,[48] laser applications appear to not only help in retaining cartilage integrity[29] and improve regenerative cartilage outcomes[49] but can induce significant functional, anatomical, and histologic cartilage and joint improvements without evidence of any adverse short or medium term side effects and this occurred consistently when two differing light wave length applications were employed.[50]

Additional current reports show the novel use of laser light applied to a scaffold system of cartilage repair appears to have the potential to produce an important combination of mechanical and biochemical cues for regulating chondrocyte proliferation.[51] Additionally, its use as a dual-bionic photothermal nanozyme constructed to mimic antioxidases/hyaluronan synthase for osteoarthritis therapy that enhances lubrication in the early stage of the disease shows anti-oxidase-like mimicking properties that may potentially promote chondrogenesis.[52]

This aforementioned ability of laser light to directly reshape or influence cartilage by accelerating its cellular mechanical stress relaxation cycle and that appears to increase cartilage cell numbers and cell proliferation activity,[53] as well as positively affecting the synthesis and secretion of extracellular cartilage matrix constituents may not only preserve cartilage, but may promote function and reduce inflammation commonly occurring in an arthritic joint.[50,54]

Shen[8] also discuss a role for lasers in the form of a photoacoustic imaging probe that can be used to monitor early cartilage degeneration and applied therapeutically could target the cartilage based collagen II peptide, which is expressed on chondrocytes and where this nano-probe can induce a localized plasmon resonance coupling and anti oxidative effect that may delay the disease development. Stem cell applications being tested to enhance cartilage repair and exposed to laser stimulation also appear promising, even in severe disease.[55]

Mechanisms of action of laser light on joint tissues that are thought to advance tissue repair probabilities and that warrant future exploration include - but are not limited to its potential to its ability to -

- Activate cellular metabolism
- Decrease production of cartilage degrading enzymes
- Foster anti-inflammatory effects
- Foster bone and cartilage preservation
- Hasten post exercise recovery
- Improve venous/lymphatic microcirculation
- Improve muscle function/locomotion
- Increase extracellular matrix protein expression
- Reduce joint effusion
- Slow pain transmission.[8,20,22,23,50,56-61]

Outcomes may depend on:
1) the osteoarthritis model;
2) the joint studied and irradiated,
3) the mode of irradiation,
4) the outcomes assessed,
5) the frequency and duration of the therapy and follow up.[62-65]

Discussion

Osteoarthritis, a prevalent disabling disease causing immense suffering, continues to impact lives as well as health care costs incrementally and negatively, despite years of research. The present overview concerning the use of laser therapy for remediating osteoarthritis disability was undertaken due to its somewhat less than universal support for its use and the ambiguous findings of some prior systematic reviews on this topic, but not others,[19,26,69] despite its promise and safety record. In this regard, in terms of favorable pain as well as healing outcomes post-laser irradiation, we did not however come across many current equivocal findings for the years 2020-2024, when compared to previous work or that attempted almost 30 or more years ago, and seems

increasingly to be advantageous to the field of osteoarthritis care in multiple ever expanding ways. Moreover, most current studies, regardless of whether they are conducted in differing osteoarthritis models, substrates, or synthetic cartilage scaffolds and stem cell cultures, results appear to strengthen the case for applying laser therapy in various dosages and wavelengths in efforts to ameliorate one or more symptoms of osteoarthritis independent of any associated placebo effect, or mode of application, as well as for cartilage protection or repair, even if this needs more sound study.[10,19,28,66,69]

Indeed, regardless of whether recent laser therapy osteoarthritis studies have been observational or controlled, using diverse high intensity or low intensity laser pulses or light emitting diodes, a reader cannot fail to be impressed with the enormous potential for laser therapy to be mobilized effectively so as to reduce osteoarthritis disability rapidly, safely, and significantly, and if carefully applied, to foster possible cartilage restoration. Moreover, it seems laser light is available universally and its favorable impacts seem to occur regardless of treatment methods and disease durations with favorable disease ameliorating and transformational outcomes and results that exceed those of placebo applications or other therapies. These effects also appear reasonably sustainable and consistent with laboratory evidence of tangible indicators of cartilage repair in moderate or sub acute cartilage lesions introduced artificially and that show great potential for alleviating suffering.

Unfortunately, the very insightful pre clinical data have not translated to a high degree into the clinical sphere to any extent to date. As well, the full scope of any long term or structural benefits is still largely unknown and it has not been the norm to examine joint structures or biomechanics pre and post laser irradiations or other possible salient mechanisms of action and outcome impacts in those clinical studies that prevail,[69,70] so what this would show, while worthy of investigation, remains uncertain at best.

It can be hypothesized however, that careful selection and delivery of laser light pulses, modes of application, and application durations designed to maximize the ability of different laser signals to influence joint structures, mechanisms that impact joint health, and the osteoarthritis cartilage repair process, may well be within reach on a large scale and with ample evidence and personal and public cost savings. In addition, the gap between the lab and the bench findings may decline if the use of more objective clinically relevant biomarkers and state of the art outcome measures were to be consistently applied, standardized and optimally exploited, including its anti-oxidative inflammatory and pain correlates, as well as its mechanical, radiological and regenerative disease correlates.

Examining the parallel role of the multiple joint manifestations of osteoarthritis that appear responsive to laser light applications, such as muscle dysfunction, depression and insomnia, and possibly obesity may prove revealing as well.

Indeed, in addition to exploring its osteoarthritis cartilage cellular impacts, establishing whether laser therapy can be designed to precisely target, provoke, or heighten the activation of endogenous opioid receptors or distant neural structures that can influence immune function and central sensitization processes causing pain and inflammation and to do this non-invasively, could have immense treatment implications, especially for older osteoarthritis cases who cannot undergo surgery or use anti-inflammatory drugs and others, while potentially permitting cartilage to be more protected from repeated loading impacts and controlling or retarding its progression.[70]

Also effective as regards other joint manifestations of osteoarthritis, such as muscle dysfunction, depression and insomnia, laser therapy appears important to continue to examine, when considering the limitations of education, exercise, surgical and pharmacologic strategies that are the mainstream currently advocated interventions for ameliorating disabling osteoarthritis.

However, to overcome current gaps and inaccuracies or discrepancies,[66] studying the nature of the pre clinical model,[67,68] plus efforts to carefully avoid trials involving concurrent multi intervention approaches plus differing standard physical therapy co intervention protocols in the future study realm may help to unmask the unique effects of laser therapy and how it can be harnessed for treating osteoarthritis. In addition, careful sampling, disease staging, instituting a washout period of at least two weeks prior to treatment session one, and controlling for activity levels between treatments are strongly indicated.

In this regard, while our review provides only a snapshot of current pre clinical studies and is not all encompassing or one that may not reflect other information sources, it does appear careful translational understandings and well designed and controlled long-term studies of osteoarthritis sub groups rather than widely diverse samples using carefully selected devices and dosages and objective outcome analyses may help us to better discern any clinically relevant impacts, especially those representing cartilage repair or protection that is

anticipated to emerge post laser irradiation.

Conclusion

With no cure, and limitations on what is safe for older adults with disabling osteoarthritis, this brief review building on others leads us to conclude that a role for laser light applications in fostering function, averting or delaying joint surgery or fostering cartilage repair or both is highly promising.

In addition, more study of this potential light energy mode of stimulation in live tissue as well as stem cells and artificial cartilage scaffolds will prove highly fruitful and clinically relevant and significant practically as well as allaying much suffering and demands on limited health care resources.

Moreover, it is believed the frequency of negative or null laser reports is more likely than not to decline as more knowledge based on research that is robust emerges highlighting and affirming the vast health potential of insightful laser applications in early and possible late stage osteoarthritis as well as post surgery, while enhancing anti-oxidative processes and supplementing medication delivery methods as indicated.

Benefits of laser therapy may be of specific interest to policy makers and primary health providers if they can reduce hospital visits, usage of intra-articular corticosteroid injections and others, plus medications listed for alleviating osteoarthritis pain and inflammation that may inhibit, rather promote cartilage reparative mechanisms. Its usage may help reduce excess opioid reliance and its dependence and mortality risk, plus a life of limited functional ability, independence losses, and progressive cartilage destruction and disease extent and severity.

This idea is not novel, but is consistent with the enormous need to identify and implement one or more novel strategies to can reduce the immense adverse impact of osteoarthritis among older adults and others, and based on current research, great advances in the ability to alleviate suffering would be expected to follow.

In the interim, and based on the body of past and present available clinical, pre clinical and cartilage repair research, the utility of low level laser applications and other forms of phototherapy may yet provide a stand alone or supplementary and safe form of intervention for ameliorating osteoarthritis pain in those patients suffering from intractable pain as well those with more acute osteoarthritis symptoms. Alone or in combination, it appears in our view that those who seek to reverse, prevent, or mitigate some aspects of osteoarthritis disability will be especially well-served and should be strongly encouraged to consider the potential value of one or more modes of laser irradiation and its possible extensive reservoir of promising applications, for example helping to provide an effective repair strategy to counter cartilage injury.[71-74]

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Conflicts of Interest

None

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